Testing stand for life tests of hydrostatic pumps with a polluted fluid

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ABSTRACT: Testing of the lifetime of hydrostatic transmissions can be done on special testing stands. Some testing stands use a pressure valve connected at the outlet of a pump. When using this design of stands, it is important to keep clear the operating fluid by filters and it is not possible to observe the influence of fluid pollution on the lifetime. The article presents a design of an electro-hydraulic testing stand with computer control system for accelerated lifetime tests of hydrostatic pumps under laboratory conditions when using a polluted operating fluid. A pump, which is mechanically connected with a hydrostatic motor, through a clutch, is an interface between the hydrostatic circuit of the tested pump and the hydrostatic circuit of the loading simulator. At lifetime testing, this interface makes it possible to use the polluted fluid in the hydraulic circuit of the tested pump, and thereby observe its influence. Instead of a polluted fluid, it is possible to use biodegradable oil and observe its influence on the lifetime of a pump. When using the same hydraulic fluid in both systems of the stand, it is possible to test two pumps at the same time.

Keywords: hydrostatic transmission; hydraulic oil PP 80; simulator of dynamic loading

Some conceptions of agricultural tractors use transmission oil as an energy carrier in the hydraulic system as well. Zetor and ZTS tractors are examples of this conception. Hydrostatic pumps PZ 2-18-KS2 and PZ 2-12-KS2, which are used in hydraulic system of tractor three-point hitch, use oil PP 80 as an operating fluid (TKÁČ, ŠKULEC 2002). The oil serves for lubrication of tractor gearbox too. Lots of known hydraulic systems for simulation of dynamic load of hydrostatic pumps use pressure valves connected at the outlet of a tested pump. The pressure valve is controlled by hand or servomotor with cams. At these circuits it is possible to achieve restricted courses of load, which are given by velocity of mechanical preset and shape of cams at cam mechanisms. Simulators, which use pressure valves connected to a pump outlet, required filtering of the operating fluid. Therefore, it is not possible to observe the influence of fluid pollution on the lifetime of hydrostatic pumps under laboratory conditions.

MATERIAL AND METHODS

When designing the testing stand, the block diagram, the scheme of which is shown in Fig. 1 will be followed. The stand will consist of essential block as follows:

- Driving electromotor, which presents a source of mechanical energy and drives the tested pump.
- Hydraulic circuit of the tested pump, which operates with polluted oil PP 80. Transfer of energy from this block to another block is realized through a clutch mechanically.
- Hydrostatic circuit of the loading simulator, which operates with "clear" fluid OHT 3.
- Control and measuring system of the testing stand, which controls function of the stand and records courses of chosen quantities, such as pressure, speed etc.
- Power supply unit, which presents a source of electric energy for parts of control and measuring system.

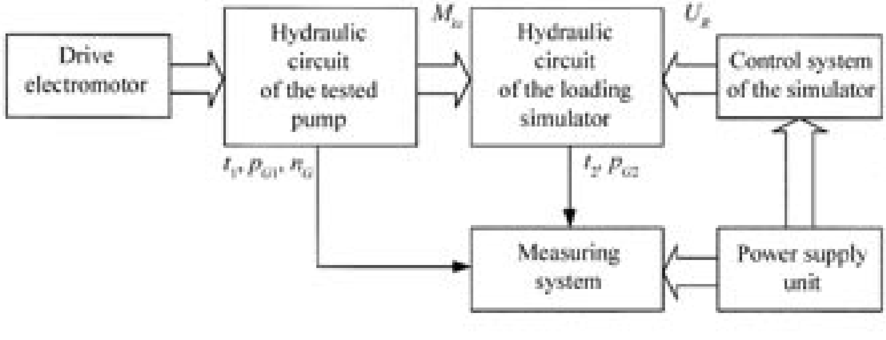

Fig. 1. Block diagram of the testing stand

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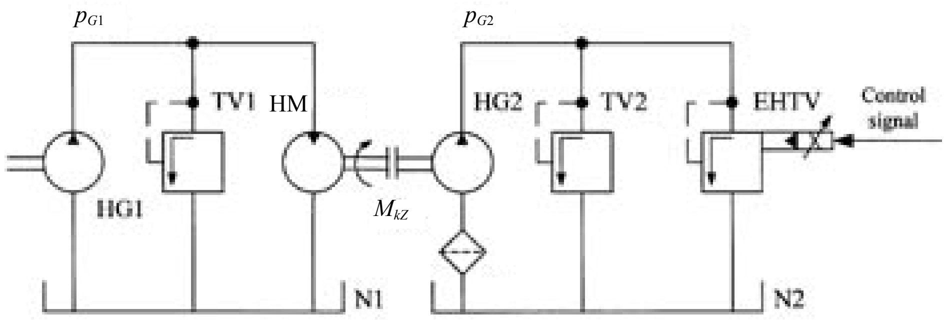

Fig. 2. Principal scheme of the testing stand

Fig. 2 presents fundamental arrangement of hydrostatic transmissions. Hydrostatic circuit, which is used for dynamic loading of the pump HG1, consists of a hydrostatic motor of the simulator HM, which is connected with a loading pump HG2, through a mechanical clutch. The outlet of the pump HG2 is connected with an electro-hydraulic proportional pressure control valve EHTV and pressure valve TV2 used as a relief valve. The outlet of the tested pump HG1 is connected with the motor HM and pressure valve TV1 used as a relief valve. There is placed a tank N1 between the inlet of the pump HG1 and the outlet of the motor HM serving for storage of the fluid with desired pollution. There is placed a tank N2 between the inlet of loading pump HG2 and the outlet of the electro-hydraulic proportional pressure valve EHTV serving for storage of the clear fluid. The fluid is kept clear by a filter Č (TKÁČ et al. 2000).

Desired change of pressure p_Z at the outlet of the pump HG1 is controlled continuously by the electro-hydraulic proportional pressure control valve EHTV. The proportional pressure valve is an active unit of the electro-hydraulic system of the stand. The proportional valve ensures the continuous conversion of control electric voltage into proportional pressure of the operating fluid. Torque of the hydrostatic motor HM is (ŽIKLA, DRABANT 1978):

$$M_{kz} = \frac{V_M \cdot \Delta p_M}{2\pi} \cdot \eta_{Mm} \qquad (1)$$

where: M_{kz} – torque on the shaft of a hydrostatic motor (N/m),
V_M – volume of a hydrostatic motor (m^3),
Δp_M – pressure drop across a hydrostatic motor (Pa).

When neglecting pressure loss in a piping between the tested pump HG1 and the loading motor HM, then

$$\Delta p_M \approx p_z \qquad (2)$$

where: p_z – loading pressure of the pump HG1 (Pa).

From Equations 1 and 2 it follows that, the hydrostatic circuit of the simulator makes it possible to change loading pressure at the outlet of the tested pump HG1 by continuous change of pressure drop across the pump HG2.

The pump HG2, which is connected with the motor HM mechanically, through a clutch, is an interface between the hydrostatic circuit of the tested pump and the hydrostatic circuit of the loading simulator. When lifetime testing, this interface makes it possible to use the polluted fluid in the hydraulic circuit of the tested pump, thereby to observe the influence of the polluted fluid to the lifetime of hydrostatic transmissions.

RESULTS AND DISCUSSION

Functional scheme of the testing stand is shown in Fig. 3 and view of the stand in Fig. 4. The tested pump HG1 (of type PZ 2-18-KS2) is connected with the gearbox P, which is driven by an asynchronous electromotor EM. When observing lifetime of the gear pump. PZ 2-18-KS2, the pump of type PZ 2-18-KS2, which is connected inversely, is used as the hydrostatic motor HM and the loading pump of the same type is used as the loading pump HG2. The outlet of the pump HG1 is connected with the outlet of the motor HM through a tubular clutch. The inlet of the pump HG1 and outlet of the motor HM is connected with the tank N1. The pressure valve TV1 of type VP 2-10, prevents the hydraulic circuit from damage. There is connected the filter C1 of type FG-II in front of the valve TV1. The oil PP 80 of tractor, after 1,200 Mh worked, is used as the operating fluid.

Generation of pressure p_{G1} at the outlet of the pump HG1 is ensured by dynamic change of torque M_{kZ} on the shaft of the motor HM. Therefore the hydrostatic simulator, which consists of the loading pump HG2, is designed. The pump HG2 is connected with the motor HM mechanically, through the clutch. The outlet of the pump HG2 is connected with the electro-hydraulic proportional pressure valve EHTV of type NW 10 (made by ORSTA HYDRAULIC) through hydraulic lines. The utilized proportional valve EHTV presents the functional block of the electro-hydraulic system of the simulator and makes it possible to convert continuous control electric voltage into proportional pressure of the operating fluid.

The circuit of the simulator is prevented from damage by pressure valve of type VP 2-10 and prevented from mechanical particles by filter Č2 of type FS 32-10-1 and of rating 10 μm. The circuit of the simulator operates with oil OTH 3, which is stored in the tank N2.

Heating both of the fluids is realized with electric flow heaters O1 and O2. There are heating cells in flow heaters of type 1206/034-3000 W. Cooling of the fluids is realized with the cooler CH1 in the circuit of the tested pump and with the cooler CH2 in the circuit of the loading pump. Pumps of type PZ 2-18-KS2 are used as pumps HG3 and HG4 for cooling and heating the fluid.

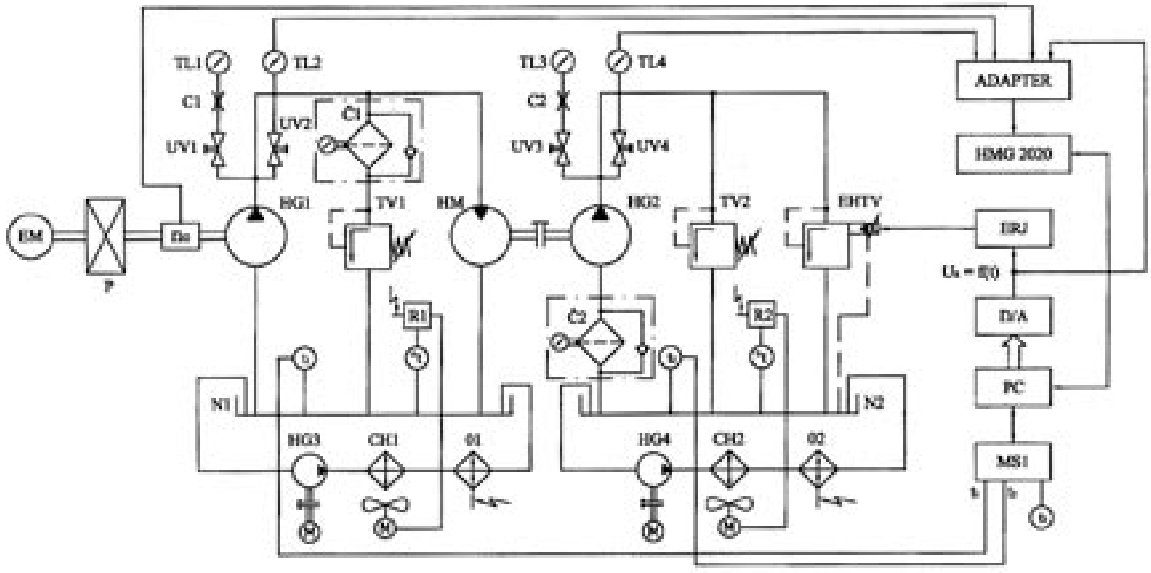

Fig. 3. Functional scheme of the testing stand with a computer control system

In order to keep optimal viscosity of the oil in both of the hydraulic systems, contact thermometers of type METRA IP 30 and range 0–200°C are built in the tank. When the temperature of the oil reaches the predetermined value of 50°C, electro motors will start up cooler fans. Pressure measuring in suction line of the pump HG2 is realized with deformation pressure gauge with flexible tube, which is a component of used filter of type FS 32-10-1. To measure pressure in pressure lines of hydraulic circuits, deformation pressure gauges with flexible tube of range 0–60 MPa and accuracy 2% are used. Its damping is realized with restrictions C1 and C2. High-pressure tubes of a bulk injection pump are used as the restrictions. Measurements of pressure and its changes are realized with HAD 3444-A-400-009 sensors (made by HYDAC, Germany) of nominal range 40 MPa. Close-up of pressure gauge in pressure lines is realized by manual shut-off valves UV1, UV2, UV3, UV4 of type 8 LUN 7373.

The testing stand is controlled with a computer control system. The control system (DRABANT 1977) consists of a computer PC, a D/A converter and an electronic control unit ERJ. Control signal is created of sampled discrete operating course, which is stored in the computer PC. A personal computer with microprocessor Intel Pentium II, RAM memory of 128 MB, operating system Windows 98 and industry PC-card of type PCL-818 is used. Created analogue signal, which represents time dependency of control voltage $U_R = f(t)$, is supplied from the PC-card into the electronic control unit ERJ, where the signal is modified into suitable shape for controlling the proportional pressure valve EHTV.

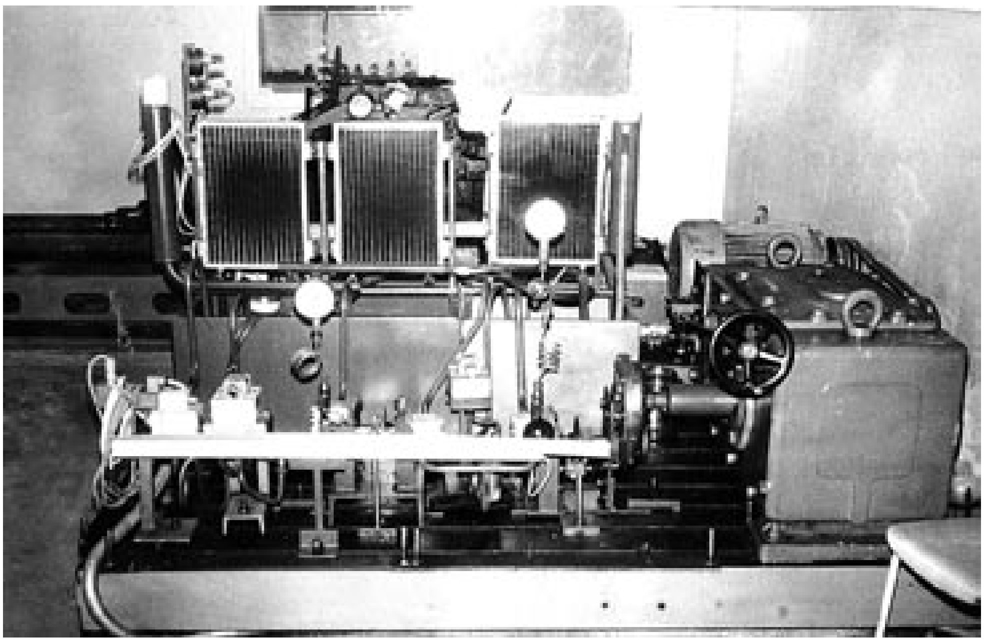

Fig. 4. View of the testing stand

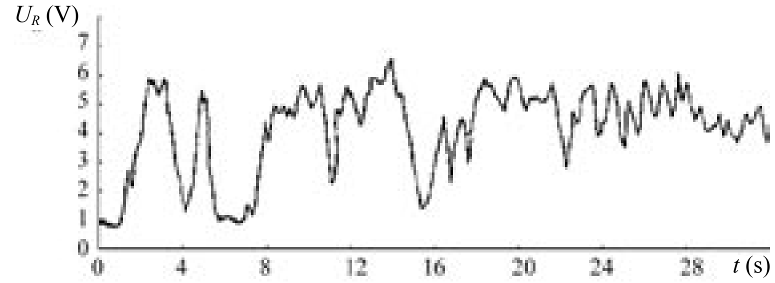

Fig. 5. Course of control voltage U_R

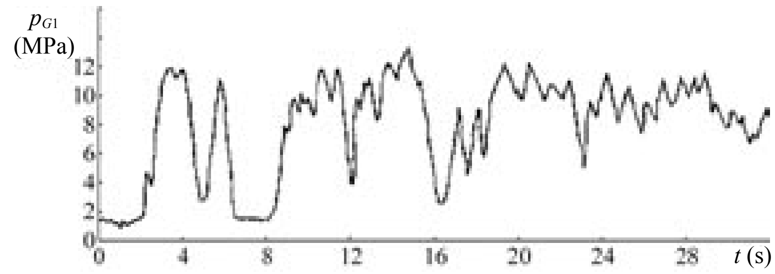

Fig. 6. Course of pressure p_{G2} in the hydrostatic circuit of the simulator

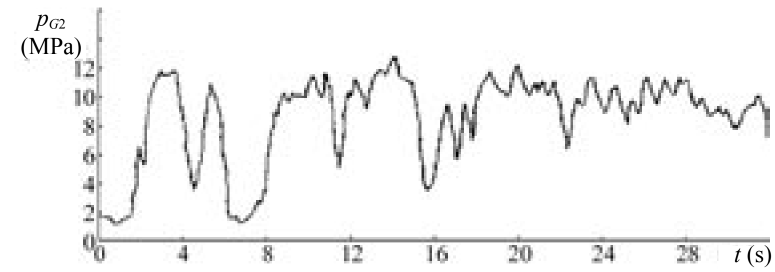

Fig. 7. Course of pressure p_{G1} in the hydrostatic circuit of the tested pump

A loading course may be given either analytically for deterministic processes or it is possible to simulate stochastic operating process. Checking measurement of the designed stand was realized when using operating control signal, which is result of measurements of a tractor ploughing set under real condition. Fig. 5 presents course of control voltage, Fig. 6 presents course of pressure in the hydrostatic circuit of the simulator and Fig. 7 presents course of pressure at the outlet of the tested pump. In order to adjudicate reliability and precision of the testing stand, courses in Fig. 5 to Fig. 7 were analyzed. Cross spectrum (cross power) between input and output is (DRABANT 1984):

$$G(f) = S_{U_R}(f) \cdot S^{+}_{pG1}(f) \qquad (3)$$

where: $S_{U_R} = FFT\,(X_{U_R})$,
FFT – fast Fourier transformation,
$S_{pG1} = FFT\,(X_{pG1})$,
$+$ – complex unity.

Cross correlation is:

$$R_{pU_R}(t) = \int_{-\infty}^{+\infty} X_{U_R}(\Psi) \cdot X_{p_{G1}}(\Psi - t)\, d\Psi \qquad (4)$$

Results of analyses are presented in Figs. 8 and 9. According to results, it has been stated, that the testing

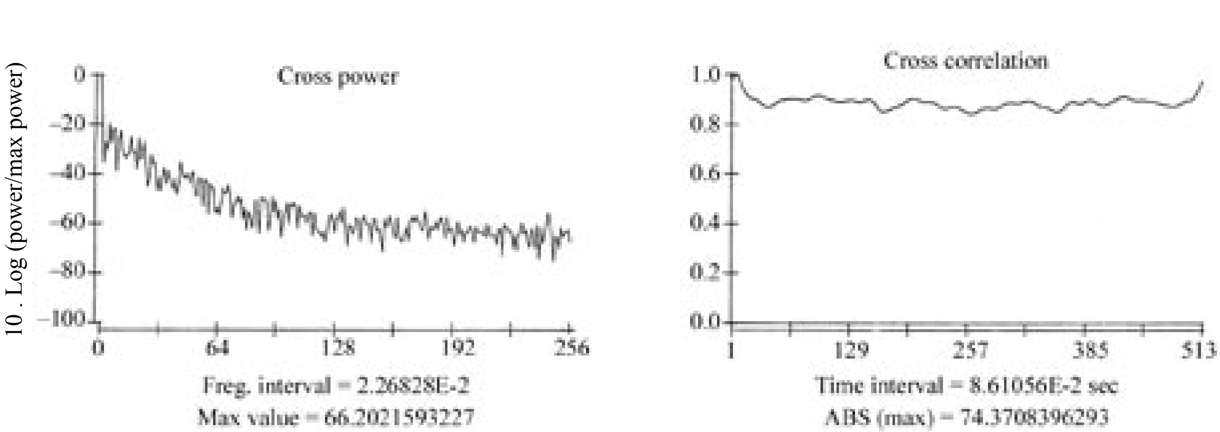

Fig. 8. Cross power and cross correlation for course of control voltage U_R and pressure p_{G1}

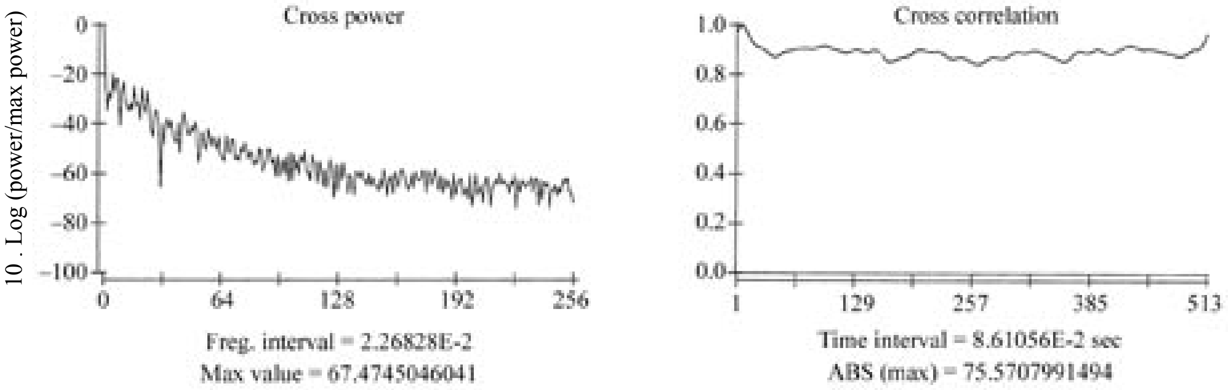

Fig. 9. Cross power and cross correlation for course of control voltage U_R and pressure p_{G2}

stand is able to simulate operating load of the tested pump under laboratory conditions with adequate precision. Cross correlation is better than 0.9 and it is not drooping. Substatic component dominates in courses of cross power.

CONCLUSION

Advantage of the hydrostatic circuit of the testing stand for accelerated lifetime tests of hydrostatic transmissions under laboratory conditions is, that used proportional pressure valve EHTV makes it possible to convert continuous control electric voltage into proportional hydraulic signal – pressure of the operating fluid. The proportional valve presents an interface between electronic and hydraulic system of the stand and makes it possible to continuously control changes of loading pressure p_{G1} at the outlet of the tested pump with PC.

The pump HG2, which is connected with the motor HM mechanically, through a clutch, is an interface between the hydrostatic circuit of the tested pump and the hydrostatic circuit of the loading simulator. At lifetime testing, this interface makes it possible to use the polluted fluid in the hydraulic circuit of the tested pump, thereby to observe the influence of the polluted fluid on the lifetime of hydrostatic transmissions.

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Skúšobný stav pre životnostné skúšky hydrogenerátorov so znečistenou kvapalinou

ABSTRAKT: Skúšanie životnosti hydrostatických prevodníkov je možné realizovať na špeciálnych skúšobných stavoch. Mnohé známe skúšobné stavy pre skúšanie životnosti hydrogenerátorov používajú tlakové ventily pripojené na výstup skúšaného hydrogenerátora. Takéto skúšobné stavy však vyžadujú filtráciu pracovnej kvapaliny a neumožňujú sledovať vplyv znečistenia pracovnej kvapaliny pri laboratórnych skúškach životnosti. V príspevku je prezentovaný návrh elektrohydraulického simulátora s počítačovým riadiacim systémom, určeného pre zrýchlené životnostné skúšky hydrogenerátorov v laboratórnych podmienkach s použitím znečistenej pracovnej kvapaliny. Rozhranie medzi hydrostatickým obvodom skúšaného hydrogenerátora a hydrostatickým obvodom simulátora zaťaženia tvorí zaťažovací hydrogenerátor mechanicky spojený s hydromotorom simulátora. Toto rozhranie umožňuje použiť pri životnostných skúškach v hydrostatickom obvode skúšaného hydrogenerátora znečistenú pracovnú kvapalinu, a tým sledovať jej vplyv. Okrem vplyvu znečistenej kvapaliny je možné sledovať životnosť hydrogenerátorov pri použití biologicky odbúrateľného oleja, resp. pri použití rovnakých pracovných kvapalín v oboch hydrostatických obvodoch skúšobného stavu je možné skúšať dva hydrogenerátory súčasne.

Kľúčové slová: hydrostatický prevodník; hydraulický olej PP 80; simulátor dynamického zaťaženia

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